THEODORE VON KÁRMÁN'S DEEPENING IMPRESS UPON AERONAUTICAL SCIENCE AND ENGINEERING

By

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It is the custom in some European countries to celebrate the birthday of the king or queen, not on the calendar date of birth, but on some day when the weather is fine and the people are free to take part in appropriate ceremonies and festivities. For similar reasons we are met here tonight to do honor on his seventy-fifth birthday to Dr. Theodore von Kármán, here present with us, although according to the calendar his seventy-fifth birthday occurred on May 11th of this year. It is my great pleasure and privilege as a friend and collaborator of nearly thirty years to speak briefly of his contributions to aeronautical science and engineering and of his inspiring leadership and influence on those around him.

We may think of von Kármán's career as roughly divided into three major periods, each of approximately a quarter of a century, centered principally in Hungary, Germany and the United States, respectively.

The first period was one of preparation. He studied under Professor Banki, one of the pioneers in fluid mechanics, at the Budapest Royal

Technical University in his native city, where he graduated with highest honors as a mechanical engineer in 1902. He spent one year in military service and three years as a research engineer in industry before leaving Budapest in 1906 at the age of 25. We have record of two papers published in this period, one his thesis on the motion of a pendulum rolling on a horizontal plane, the other on the theory of buckling and compression tests of long columns. Since both were in the Hungarian language, there are few, if any, in this audience who have read them.

The second quarter-century was spent in Germany, the first six years at Göttingen, the next 18 at Aachen. After three years' study of mathematics, physics, and mechanics he received his degree of Dr. Phil. (PhD), his dissertation being a report of investigations of buckling which fully established the double-modulus theory of the plastic buckling of columns, which bears his name jointly with Considère and Engesser. He became Privat docent and assistant to Prandtl, who was only six years his senior. In this period von Kármán began a rate of scientific activity which led to the publication of a new paper or book approximately every 4 1/2 months, a rate which he has continued ever since. His scientific interest was mainly in buckling, plastic flow, and theory of failure of materials and he was the first to conduct experiments in which specimens were subjected to external hydraulic pressure. However, his interests were wide and he worked with the physicist Born on the vibrations of crystal lattices and the theory of specific heat. In fluid mechanics he published a paper on shock waves in gas jets, and another in which

he showed that some results of the physical chemist, Bose, on pressure drop in the flow of viscous organic liquids in pipes could be unified when plotted on the basis of Reynolds number. Finally in this period, as so charmingly told in his recent book, "Aerodynamics: Selected Topics in the Light of Their Historical Development," von Kármán became interested in the troubles of his colleague, Hiemenz, who was trying to obtain symmetric flow of water around a cylinder to study boundary layer separation. But every day Hiemenz answered von Kármán's friendly inquiry, "It always oscillates." von Kármán proved that the symmetric arrangement of vortices in the wake of a cylinder was unstable and that the asymmetric arrangement could be stable for a certain ratio of the distance between the rows to the distance between the two consecutive vortices of each row. He also computed the drag from the momentum carried by the vortex system. As a result this arrangement of vortices will be forever known as the Kármán vortex street, or in more literary circles, as the Kármán vortex trail.

In 1912 von Kármán was appointed Director of the Aerodynamics Institute at Aachen, a position which he held until 1930. The Aachen period was one of rapid growth to eminence both on the part of the man and the institution. von Kármán flowered as leader of research and inspiring teacher. He traveled and lectured widely, making many new personal friends and attracting students from many countries. In the May issue of Zeitschrift für Flugwissenschaften, which, like the May issue of the Journal of the Aeronautical Sciences, is devoted to papers in recognition of von Kármán's seventy-fifth birthday, Frank Wattendorf describes von Kármán's visit to the Massachusetts Institute of Technology in 1926

and his own captivation by the inspiring presentation of the lecturer, so much so that he sought and obtained permission to prepare his thesis at Aachen under von Kármán.

Aachen and Göttingen developed a friendly rivalry and the scene of the contest was often the meeting of the International Congress of Applied Mechanics, an international activity for whose initiation von Kármán was largely responsible. Following World War I he took the initiative in arranging a meeting of scientists from many nations at Innsbruck to discuss aerodynamics and hydrodynamics. This highly successful meeting led to the First International Congress of Applied Mechanics held in Delft in 1924.

I have heard described the race to produce an engineering formula for skin friction in turbulent flow in time for the Third Congress at Stockholm in 1930. The Aachen group won. von Kármán introduced his similarity theory of turbulence which led to the logarithmic velocity distribution and the turbulent skin friction law known by his name.

A little of the flavor of the time and of the working habits of our guest of honor may be appreciated from the following story told to me by Wattendorf. Aachen is near the Dutch border and von Kármán lived in the Dutch town of Walz, just over the border, the two cities being connected by a street car line. von Kármán works at his best in the evening hours and Wattendorf frequently worked with him at his home. The last street car left at midnight and von Kármán escorted his collaborator to the car line, continuing the scientific discussion en route. On this particular

evening a new idea struck just as the street car arived. von Kármán began writing equations on the side of the street car. The conductor waited patiently. As the writing and discussion continued, the conductor coughed gently and indicated that it was time to depart. "One moment, please," said the professor. The mathematical manipulations continued. The conductor became more plaintive. "Just another moment!" Finally, the conductor became insistent. "Herr professor, we must depart!" The car moved off just as the solution was finished. Unfortunately Wattendorf could not remember the steps and could not see the writing by leaning out the window. So, busy fellow, at each street car stop, Wattendorf dashed off the car, copied a few lines, and jumped on again as the car left. Fortunately, there were enough stops to get it all down before arrival at Aachen.

During the Aachen period von Kármán's interest turned largely although not completely to hydro- and aerodynamics. Early in this period came the Kármán integral relation for the approximate solution of the equations of the laminar boundary layer. Certain papers relating to pressure distribution on airship models, and impact of seaplane floats, hint at his activities as consultant on practical engineering matters to the Zeppelin, Junkers, and other aircraft companies, an important aspect of his career that is not well documented. There were other papers on airfoil theory, stability of laminar flow, and on various topics in elasticity and strength of materials and structures.

Aeronautical science and engineering in the United States owes a great debt to the Daniel Guggenheim Fund for the Promotion of Aeronautics

for bringing von Kármán to the U. S. in 1926 for visits and lectures. It was at this time that I and many in this room first met our guest of honor. I remember the inspiration of his first visit to the laboratory at the National Bureau of Standards where a small group of us were interested in wind tunnel turbulence and boundary layer flow. It is hard to describe the quality and impact of that first impression to one who has not experienced it. In a letter by a member of this audience which our guest has not yet seen, it is expressed as follows: "von Kármán, despite who he is, talks with any one of us, another and lesser man, as though that man were von Kármán, and he, von Kármán, the one learning from the master."

Following a trip around the world, and two years of oscillation between Aachen and Pasadena, von Kármán in 1930 became Director of the Guggenheim Aeronautical Laboratory at the California Institute of Technology (GALCIT). The GALCIT period was again one of great personal output of creative scientific work, of leading and guiding the growth of a world center of aeronautical education and research, and of significant engineering consultation on important industrial, state, and national projects. Some of his most outstanding papers of this period are those on the statistical theory of turbulence, the resistance of slender bodies at supersonic speeds, similarity theory for linearized supersonic flow, boundary layer in compressible fluids, analogy between supersonic flow in gases and supercritical flow of water in open channels, airfoil theory for non-uniform motion, analogy between fluid friction and heat transfer, Kármán-Tsien relation for compressible flow pressure distributions, and

non-linear buckling phenomena in curved structures. One is almost forced to list every paper by any reasonable standard of importance of the contribution.

In the lobby of the IAS building on Monday, I heard the statement that von Kármán's lectures are such models of clarity that they can be understood by anyone no matter which of the dozen languages used of which he is master, including Chinese. I have heard that he sometimes absent-mindedly began his Caltech lectures in German, and the class did not discover it for some minutes. His accent in speaking English has been the subject of many wisecracks including the claim by Tom Lanphier that von Kármán has retained his original accent purposely for 30 years for commercial purposes. However, there is no doubt that von Kármán's English has now become a new international language.

The Pasadena period ended in 1944 when von Kármán went to Washington on leave of absence at the request of General H. H. Arnold to advise on the future applications of science to the mission of the Air Force. He organized the Scientific Advisory Group of the Army Air Force, a group which did serious scientific work as a basis for giving advice, somewhat of a novelty for scientific advisors. This group later became the Air Force Scientific Advisory Board. As deputy scientific director of the Scientific Advisory Group I had the inspiration of going with him to Europe to study the use of science in warfare by the European nations, and to learn of new developments in science and technology. The results of the work of the Group are given in one volume entitled,

"Where We Stand," and a series of 30 volumes under the general title, "Toward New Horizons." These reports are still classified but those who have read them are familiar with their continuing influence on the course of Air Force research and development. The present status of research and development at a high level in the Air Force organizational structure resulted from the later activities of the Scientific Advisory Board, of which he remained the active chairman until 1954. One of his important scientific papers during this period was on the similarity law of transonic flow. In 1950 there appeared his theory of the propagation of plastic deformation in solids (theory of plastic waves) which he had worked out in 1941 in a letter written on a New York Central train.

When von Kármán arrives in any city in the world, word of his arrival seems to spread quickly and mysteriously to his many friends and admirers so that he is soon surrounded. He has developed a world-wide community of scholars and friends. After World War II he became concerned about the human problems of able scientists of the free nations of Europe who had no opportunity to use their talents for useful purposes and the consequent waste of scientific manpower. In February 1951 with the support of the U. S. Air Force and the Standing Group of the North Atlantic Treaty Organization he called a conference in Washington of leading aeronautical research directors of the NATO nations. This conference recommended the establishment of an Advisory Group for Aeronautical Research and Development (AGARD) within the NATO framework with von Kármán as chairman. First approved for two years on a trial

basis, AGARD was given continuing status in 1954. Read Clark Millikan's article in the May issue of the Journal of the Aeronautical Sciences for a brief account of its accomplishments.

I have personally seen many American scientists and engineers make their first contact with AGARD, skeptical at first but soon enthusiastic supporters as they became familiar with its accomplishments. The diplomatic and political skill of the "Boss," as he is affectionately known to his staff, is unparalleled but that is too long a story to tell here. During this AGARD period he has continued his personal scientific work by leadership in establishing the new science of aero-thermo-chemistry in the study of combustion processes, and by lecturing and writing in this field.

Although I have merely mentioned the titles of a few of von Kármán's more than 135 books and papers, I believe that members of this audience recognize the powerful influence of those papers on aeronautical science and engineering and even on scientists and engineers who have not had the good fortune to know him personally. But far more important is the ever-widening influence of his personality spread by the hundreds of students from Aachen and Pasadena who were taught to isolate the essential physical concepts of a complex engineering problem, to apply suitable mathematical analysis, and to evaluate the results in practical terms. They have been inspired to their maximum of creative effort and infected with enthusiasm for scientific work. Many of them have been able to transmit this inspiration to their own students and collaborators, becoming leaders in their own right. In this way von Kármán's personality and work are making an ever-deepening impress.

Those of us within his large circle of friends and collaborators can never forget his human qualities, his friendliness, his sense of humor, his interest in each person as an individual, and his stimulating views on art, philosophy, and other human affairs. His kindly consideration may be illustrated by another true story. Because of pressure on his time, it became necessary for von Kármán to examine five PhD candidates at once at a single session. After a brief period of questioning, he expressed himself as satisfied and dismissed the candidates. But one remained to remonstrate with him. "But, Doctor, you didn't ask me a single question." "Yes," said the Doctor, "but you nodded so intelligently."

Dr. von Kármán, we hope that you have taken some pleasure in this account of "This is Your Life," not done quite in the Ralph Edwards style, but perhaps bringing back to you pleasant memories. But we hope you don't spend too much time looking back, because we look forward to your future contributions and ever-deepening influence on aeronautical development. May you enjoy good health, happiness, and prosperity for many years to come.

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